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**Roy et al.**

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(54) **HIGH DENSITY INTERCONNECT DEVICE AND METHOD**

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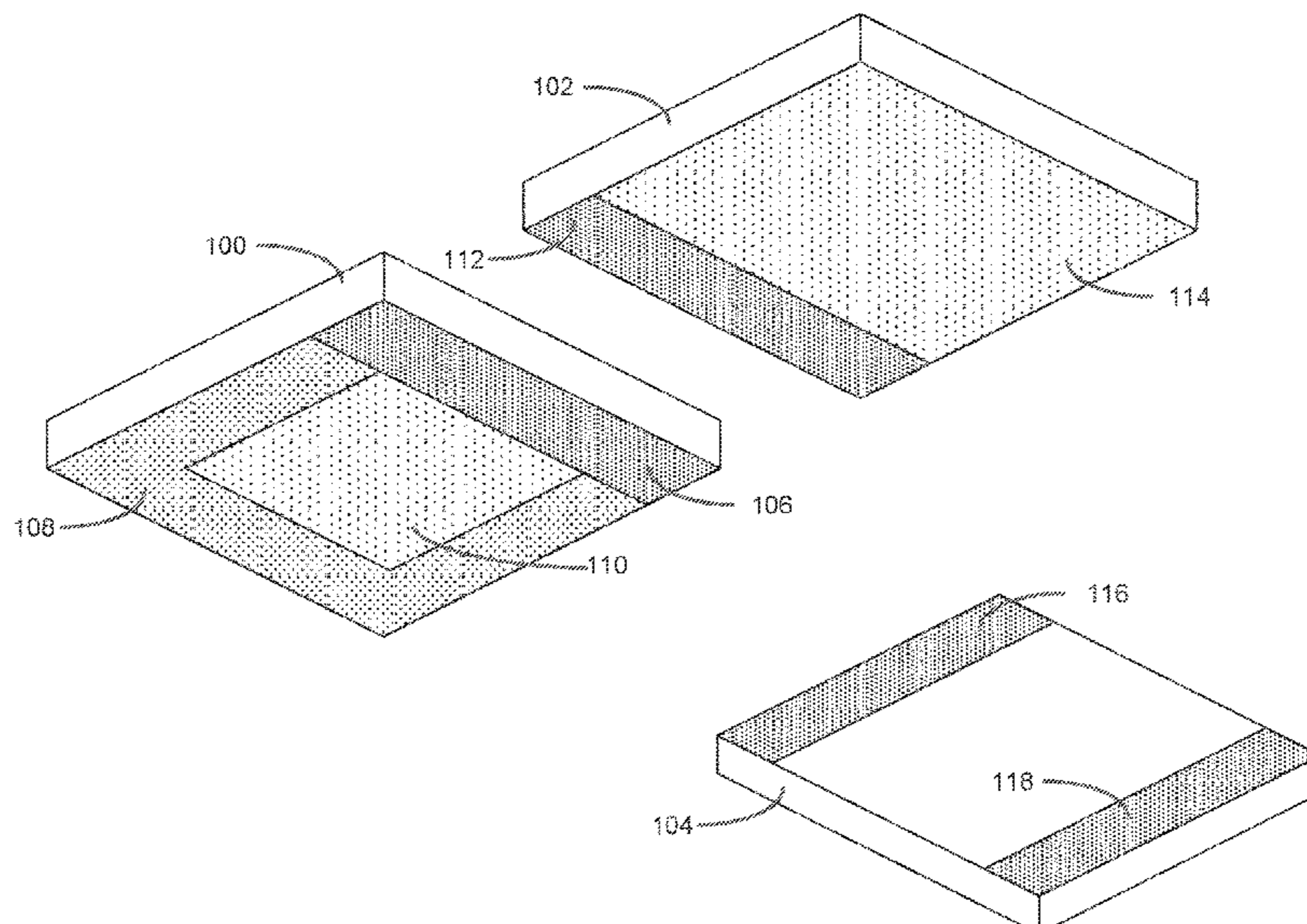
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(57) **ABSTRACT**

Embodiments that allow both high density and low density interconnection between microelectronic die and motherboard via. Direct Chip Attach (DCA) are described. In some embodiments, microelectronic die have a high density interconnect with a small bump pitch located along one edge and a lower density connection region with a larger bump pitch located in other regions of the die. The high density interconnect regions between die are interconnected using an interconnecting bridge made out of a material that can support high density interconnect manufactured into it, such as silicon. The lower density connection regions are used to attach interconnected die directly to a board using DCA. The high density interconnect can utilize current Controlled Collapsed Chip Connection (C4) spacing when interconnecting die with an interconnecting bridge, while allowing much larger spacing on circuit boards.

**18 Claims, 3 Drawing Sheets**



**Related U.S. Application Data**

continuation of application No. 15/438,321, filed on Feb. 21, 2017, now Pat. No. 10,446,499, which is a division of application No. 14/518,421, filed on Oct. 20, 2014, now abandoned, which is a continuation of application No. 13/722,128, filed on Dec. 20, 2012, now Pat. No. 8,866,308.

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See application file for complete search history.

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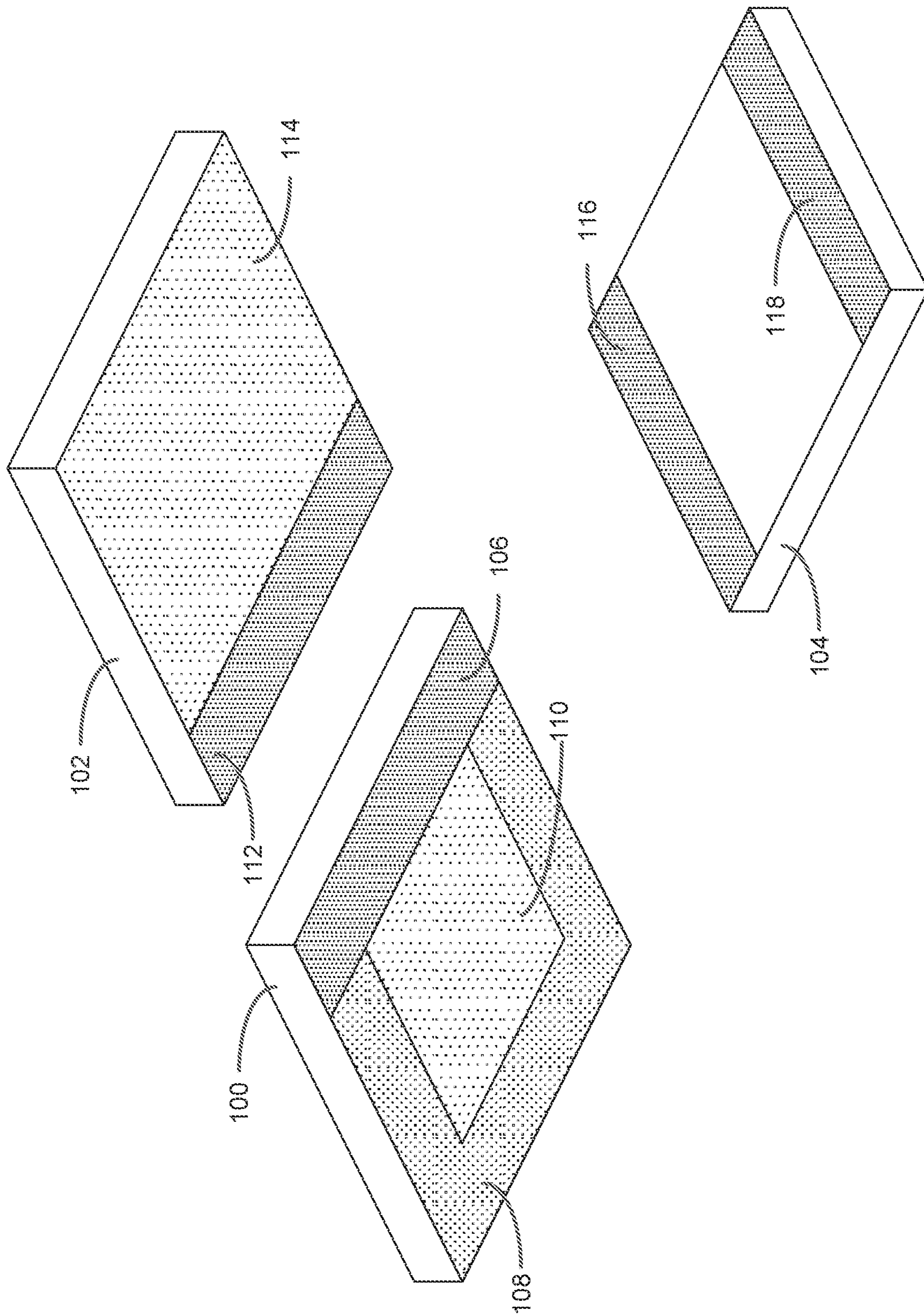


FIG. 1

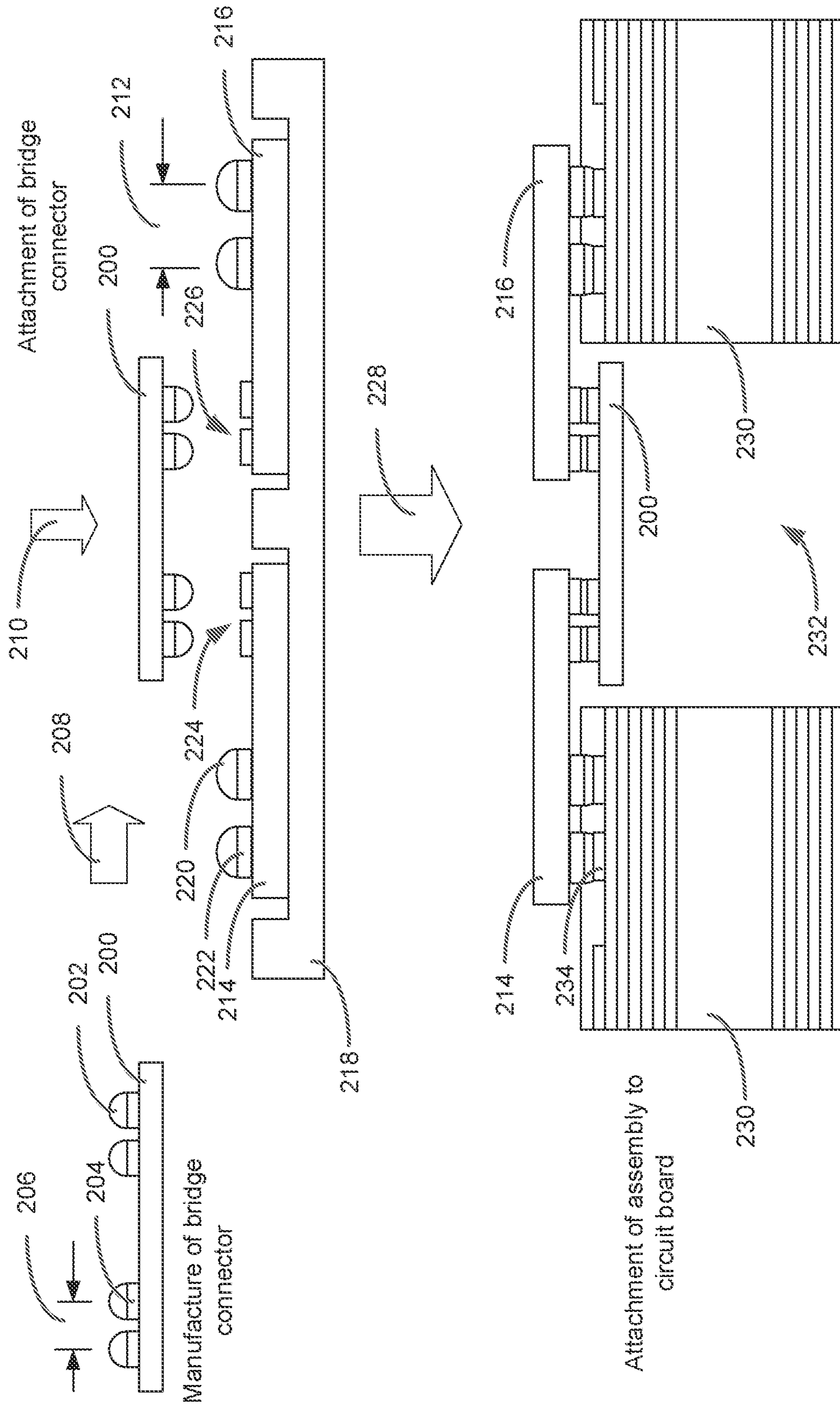


FIG. 2

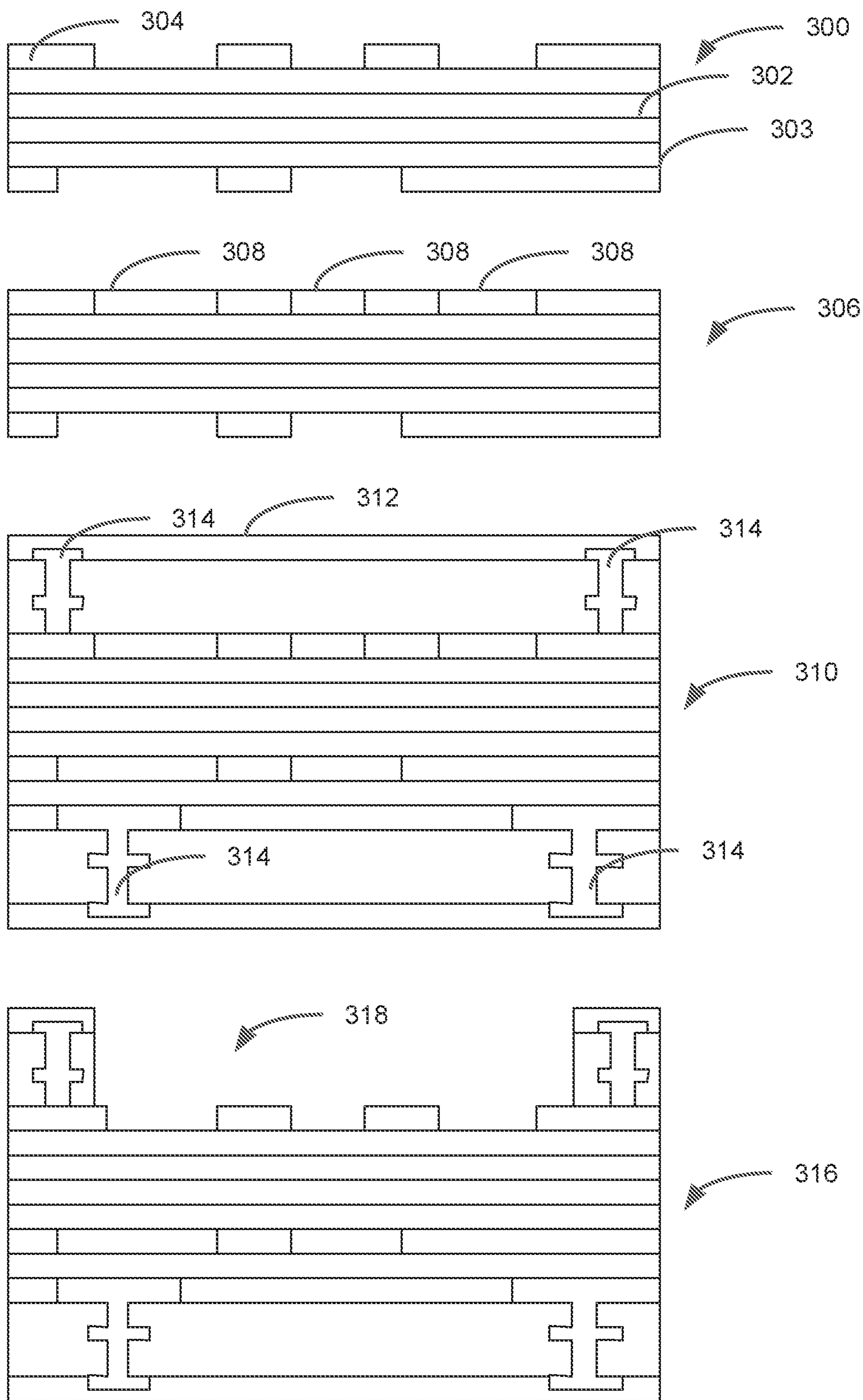


FIG. 3

## HIGH DENSITY INTERCONNECT DEVICE AND METHOD

This application is a continuation of U.S. application Ser. No. 16/601,297, filed Oct. 14, 2019, which is a continuation of U.S. application Ser. No. 15/438,321, filed Feb. 21, 2017, now issued as U.S. Pat. No. 10,446,499, which is a divisional of U.S. application Ser. No. 14/518,421, filed Oct. 20, 2014, which is a continuation of U.S. patent application Ser. No. 13/722,128, filed on Dec. 20, 2012, now issued as U.S. Pat. No. 8,866,308, all of which are incorporated herein by reference in their entirety.

### TECHNICAL FIELD

Embodiments pertain to integrated circuit (IC) dies, die packages, and associated methods. More particularly, embodiments pertain to using an interconnecting bridge such as a silicon bridge to interconnect dies with a high density interconnect.

### BACKGROUND

Direct Chip Attach (DCA) on board is a concept that may allow significant cost savings by eliminating the package. However, board design rules have not scaled at the same rate as Controlled Collapsed Chip Connection (C4) bump pitch. Thus, in order to use DCA, the bump pitch of the chip die needs to be large enough to accommodate the board design rules, and that size bump pitch would be much larger than current technology allows for dies. This limits the number of interconnects that may be made using DCA.

As long as the hump pitch of the die is large enough to accommodate the board pad size and the line/space rules, DCA remains an attractive solution. However, in the System On Chip (SOC) area and in other high density interconnect applications, DCA is yet to be considered due to the mismatch between the C4 bump pitch scaling of current generation SOC die and the board pad size and line/space rules.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates microelectronic dies, according to some embodiments;

FIG. 2 illustrates a process to interconnect microelectronic dies and to mount interconnected microelectronic dies, according to some embodiments; and

FIG. 3 illustrates a process to create a recess in a circuit board to receive a bridge, according to some embodiments.

### DETAILED DESCRIPTION

The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

FIG. 1 illustrates microelectronic dies, according to some embodiments. The illustrated embodiments allow dense interconnects between dies in DCA type situations while still accommodating board pad size and line/space rules. FIG. 1 illustrates two dies **100** and **102**, and an interconnecting bridge **104** suitable for interconnecting the two dies. Such a bridge may be, for example, a silicon bridge. In some

embodiments one die, such as die **100**, may be a processor die such as SOC, Central Processing Unit (CPU), Digital Signal Processor (DSP), Graphics Processing Unit (GPU), Advanced Processing Unit (APU), or other type of processor.

Die **100** has a high density interconnect **106**. High density interconnect **106** has a low bump pitch to allow a high number of connections in a small area. In one example, the bump pitch is from about 30  $\mu\text{m}$  to about 90  $\mu\text{m}$ . A high density interconnect may be used to connect die **100** to another die where a high number of connections would be advantageous. An example would be where die **100** is a SOC and is connected through high density interconnect **106** to a memory die.

Die **100** may contain other connection regions spread around different parts of the die. In the illustrated embodiment, die **100** has connection region **108** around the remaining sides of the die and connection region **110** located more centrally. The bump pitch of connection region **108** and the bump pitch of connection region **110** allow DCA of die **100** to a circuit board. As such, the bump pitch of connection region **108** and the bump pitch of connection region **110** are sized to accommodate the pad size and line/space rules of the board. The bump pitch of connection region **108** may be the same as or different than the bump pitch of connection region **110**, depending on the embodiment. This will result in a bump pitch for connection region **108** and connection region **110** that is greater than the bump pitch of high density interconnect **106**. Current design rules allow a spacing for a High Density Interconnect (HDI) type board that is no tighter than about 60  $\mu\text{m}$  to about 75  $\mu\text{m}$ .

When die **100** is a processor die, such as a SOC die, high density interconnect **106**, which is located adjacent to one side, may house the memory connections. Other input/output connections may be contained in connection region **108**, which is adjacent to the remaining three sides. Finally, power connections may be very sparsely populated (relatively) without affecting performance. Therefore, power connections may be more centrally located as in connection region **110**. Additionally, or alternatively, some power connections may be interleaved in other regions as desired. In this example, the bump pitch of connection region **108** may be the same as, or different than, the bump pitch of connection region **110**.

Die **102**, which may be a memory die or some other type of die, also has a high density interconnect **112**. High density interconnect **112** has a low bump pitch to allow a high number of connections in a small area. In one example, the bump pitch is from about 30  $\mu\text{m}$  to about 90  $\mu\text{m}$ . The bump pitch of high density interconnect **112** may match that of high density interconnect **106**.

Die **102** may also have connection region **114**. In one example, die **102** is a memory die and connection region **114** contains power connections for the die. The bump pitch in connection region **114** may be sized to accommodate DCA of die **102** to a circuit board, such as a HDI type board. As such, the bump pitch of connection region **114** will be no tighter than about 60  $\mu\text{m}$  to about 75  $\mu\text{m}$  using current pad and line/space rules.

Interconnecting bridge **104** is a die designed to interconnect die **100** and die **102**. To accomplish this, interconnecting bridge **104** has two high density interconnects, **116** and **118**. The bump pitch of high density interconnect **116** is sized to match the bump pitch of high density interconnect **106**, and the bump pitch of high density interconnect **118** is sized to match the bump pitch of high density interconnect **112**. Typically the bump pitch of high density interconnect

116 will match that of high density interconnect 118, but different bump pitches may be used.

FIG. 2 illustrates a process to interconnect microelectronic dies and to mount interconnected microelectronic dies, according to some embodiments. In FIG. 2, the process begins with the manufacture of an interconnect bridge (e.g., a silicon bridge) 200. The bridge, such as bridge 104 of FIG. 1, has high density interconnects at its ends to interconnect dies, and appropriate interconnections between the two high density interconnects are made in order for the dies to be connected. The high density interconnects have connection pads (or bumps) 204, which have a bump pitch 206. As previously mentioned, the bump pitch for the high density interconnects may be the same or may be different, depending on the particular embodiment. As illustrated in FIG. 2, the connection mechanism such as solder on pads may be provided with higher temperature solder 202 (higher in comparison to 224) during the manufacturing process.

Once the interconnecting bridge 200 is manufactured, it may be used to interconnect other die. In FIG. 2, this transition is illustrated by arrow 208. In the particular example of FIG. 2, interconnecting bridge 200 will be used to interconnect die 214 and die 216. Die 214 and die 216 have high density interconnects located so that the distance between the high density interconnects may be bridged by interconnecting bridge 200 when they are correctly oriented. Specifically, in FIG. 2, the high density interconnects are located adjacent to an edge of the die, as illustrated by 224 and 226. The bump pitch of the high density interconnects is sized to match the corresponding high density interconnect of interconnecting bridge 200. Since interconnecting bridge 200 has previously been manufactured with high temperature solder 202 covering the connection pads of its high density interconnects, it is generally not necessary to provide the die's high density interconnects with high temperature solder, although this is simply an example.

Die 214 and die 216 also have a connection area with connection pads 222 with bump pitch 212. Connection pads 222 may also be provided with solder 220 during manufacture of die 214 and die 216 (or as part of a separate process). The bump pitch 212 is sized appropriately for attachment to a circuit board, as explained below. Although FIG. 2 illustrates all connection areas of both die 214 and die 216 having the same bump pitch, that is simply an example, and different connection areas within a die or different connection areas between dies may have different bump pitch.

Die 214 and die 216 may be placed in a carrier 218 and oriented so that their high density interconnects are located toward one another. Interconnecting bridge 200 is flipped and attached to die 214 and 216 through a bonding process, such as thermal compression bonding, solder reflow, and the like. This is illustrated by arrow 210.

After die 214 and die 216 are interconnected by interconnecting bridge 200, they may be mounted on a circuit board, such as a HDI type board. In FIG. 2, this transition is illustrated by arrow 228.

In FIG. 2, an appropriate board is illustrated by board 230. Board 230 is typically a HDI type board with multiple layers and microvias on the top one to three layers. In preparing the board, the high density interconnect may be called out specifically along with the connection points 234 (and their associated bump pitch) in the die (such as die 214 and die 216) that will directly attach to the board.

The circuit board may be prepared by creating a hole or recess where interconnecting bridge 200 will reside when the assembly is attached to the board. In FIG. 2 that hole is illustrated by 232. Although a hole between all layers of

board 230 is illustrated, this is an example only. A recess sufficient to accommodate the interconnecting bridge may also be used.

The assembly of die 214, die 216, and interconnecting bridge 200 is flipped and attached to board 230 using a DCT technology, as illustrated in FIG. 2. In attaching the assembly to board 230, a solder melting temperature hierarchy may be maintained so that the solder joints of already bonded interfaces do not melt when later solder joints are made. If desired, a material, such as an epoxy or some other material, may be placed in hole 232 in order to provide mechanical support for interconnecting bridge 200, depending on the embodiment. Such mechanical support is, however, optional.

Using an interconnecting bridge 200 to interconnect die 214 and 216 can allow a very high density interconnection to be made between, for example, a SOC die and a memory die, while allowing greatly relaxed tolerances on circuit board production and assembly. Thus, the entire assembly can be mounted to the board 230 using Surface Mount Technology (SMT) because the board pitch can be, for example, from about 250  $\mu\text{m}$  to about 400  $\mu\text{m}$  while still maintaining tight bump pitch on the high density interconnects (for example, from about 30  $\mu\text{m}$  to about 90  $\mu\text{m}$ ).

FIG. 3 illustrates a process to create a recess in a circuit board to receive a bridge, according to some embodiments. The process begins as illustrated in 300 when planar copper is patterned with subtractive or semi-subtractive on the layer to be connected to the component along with other patterning. This can result in multiple layers 302 (typical) and various features, such as 304. In the figure, the bridge attachment side is shown at the top of the board 303.

In 306, a releasable layer 308 is applied through squeeze. The thickness of the layer 308 is approximately the same thickness as the copper of that layer.

In 310, subsequent layers are added to create various desired features, such as microvia 314, until solder resist layer 312 is applied, and all layers of the board are complete.

In 316, recess 318 is created by removing the buildup layers where the bridge is to reside. This can be accomplished through laser scribing or by using a photo sensitive material in the area, which is later to be removed, and then using light to remove the photo sensitive material. After the buildup layers are removed, the releasable layer is removed, and a de-smear process is used to clean out the remnants from the releasable layer.

The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments in which the disclosure may be practiced. These embodiments are also referred to herein as "examples." Such examples may include elements in addition to those shown or described. However, the present inventors also contemplate examples in which only those elements shown or described are provided. Moreover, the present inventors also contemplate examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein.

In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless



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otherwise indicated. In this document, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Also, in the following claims, the terms “including” and “comprising” are open-ended, that is, a system, device, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms “first” “second,” “third,” and so forth are used merely as labels, and are not intended to impose numerical requirements on their objects.

The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects (hereof) may be used in combination with each other. Other embodiments may be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is provided to comply with 37 C.F.R. § 1.72(b), to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. This should not be interpreted as intending that an unclaimed disclosed feature is essential to any claim. Rather, inventive subject matter may lie in less than all features of a particular disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separate embodiment, and it is contemplated that such embodiments may be combined with each other in various combinations or permutations. The scope of the inventive material should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. A microelectronic die comprising:
  - a high density interconnect located adjacent to a first edge on a first surface, the high density interconnect having a first bump pitch, the high density interconnect bump pitch sized to connect to an interconnecting bridge;
  - a connection region located adjacent to a second edge on the first surface, the connection region having a second bump pitch, wherein the second bump pitch is a direct chip attach (DCA) pitch sized to attach to a circuit board; and
  - a power connection region located on the first surface interior to the high density interconnect and the connection region.
2. The die of claim 1, wherein the first bump pitch is from about 30  $\mu\text{m}$  to about 90  $\mu\text{m}$ .
3. The die of claim 1, wherein the connection region includes power connections.

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4. The die of claim 1, wherein the connection region includes input/output connections.

5. The die of claim 1, wherein the die is a System On Chip (SOC) die.

6. The die of claim 1, wherein the die is a memory die.

7. The die of claim 1, wherein the first bump pitch is less than the second bump pitch.

8. The die of claim 1, wherein the first bump pitch is less than the second bump pitch, and wherein the first bump pitch is from about 30  $\mu\text{m}$  to about 90  $\mu\text{m}$ .

9. A microelectronic die comprising:
 

- a high density interconnect located adjacent to a first edge on a first surface, the high density interconnect having a first bump pitch, the high density interconnect bump pitch sized to connect to an interconnecting bridge;
- a connection region located adjacent to a second edge on the first surface, the connection region having a second bump pitch; and
- a power connection region located on the first surface interior to the high density interconnect and the connection region.

10. The die of claim 9, wherein the first bump pitch is less than the second bump pitch.

11. The die of claim 9, wherein the second bump pitch is less than a power connection region bump pitch.

12. The die of claim 9, wherein the second bump pitch is about equal to a power connection region bump pitch.

13. The die of claim 9, wherein the second bump pitch is a direct chip attach (DCA) pitch sized to attach to a circuit board.

14. The die of claim 9, wherein the connection region located adjacent to the second edge on the first surface includes input/output connections.

15. A microelectronic die comprising:
 

- a high density interconnect located adjacent to a first edge on a first surface, the high density interconnect having a first bump pitch, the high density interconnect bump pitch sized to connect to an interconnecting bridge;
- a connection region on the first surface, the connection region having a second bump pitch, wherein the second bump pitch is a direct chip attach (DCA) pitch sized to attach to a circuit board; and
- a power connection region located on the first surface interior to the high density interconnect and the connection region.

16. The die of claim 15, wherein bumps of the connection region having the second bump pitch are located adjacent to a second edge on the first surface of the die.

17. The die of claim 15, wherein the connection region includes power connections.

18. The die of claim 17, wherein the connection region includes input/output connections.

\* \* \* \* \*